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(58) Field of search
G1U
G4D
G4H
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Selected US specifications from IPC sub-class G01R

(54) Utility meter

(57) The utility meter (20) is a microprocessor-based circuit using Hall effect electric current sensors to measure power usage by residential and commercial customers. An analog signal from the Hall effect sensor is converted to a digital signal which is fed to the microprocessor for analysis and storage in random access memory. Using a real time clock, the microprocessor determines time of use information which is also stored in random access memory. The memory may be remotely interrogated via a telephone line (32) or serial communication link. If desired, the meter can receive utility usage inputs from other utility meters, such as water, (38) gas, (40) etc.

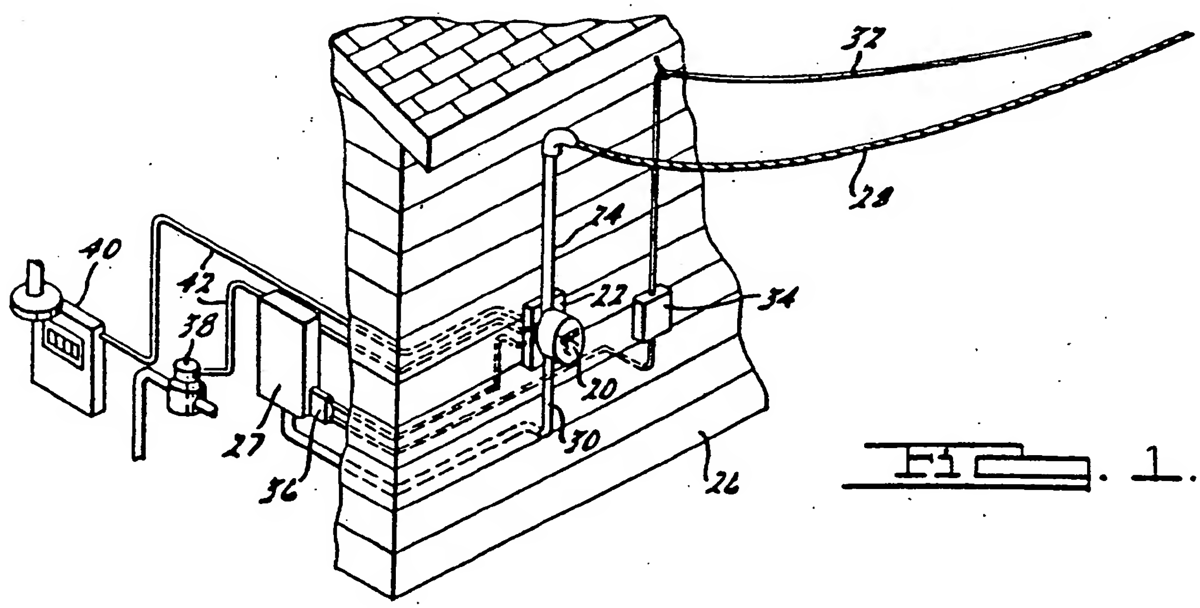

FIG. 1.

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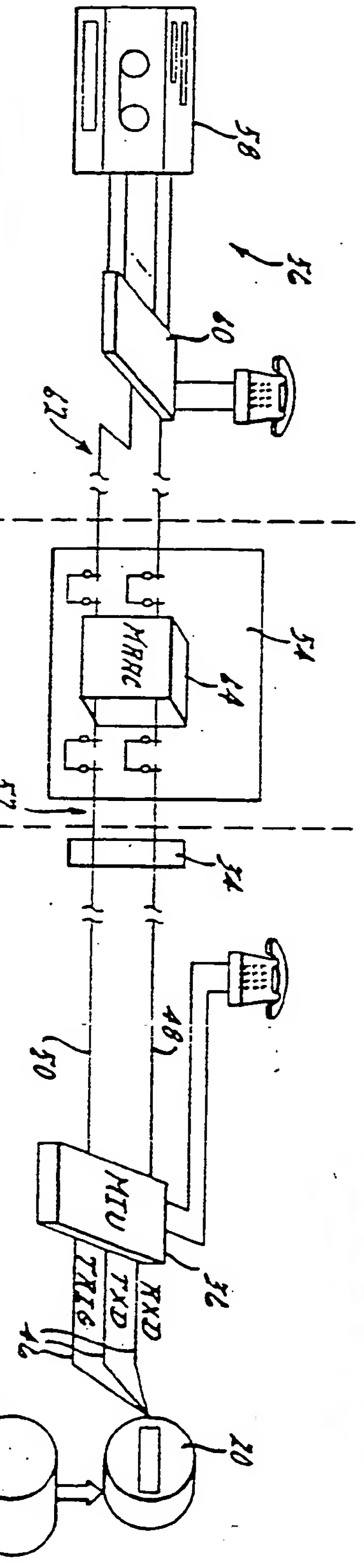

FIG. 2

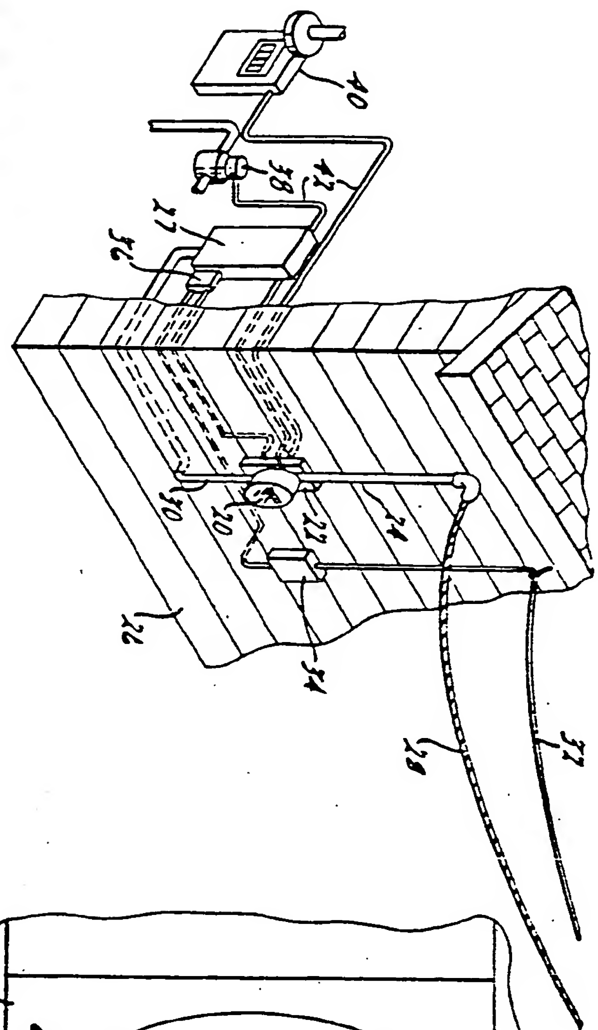

FIG. 1

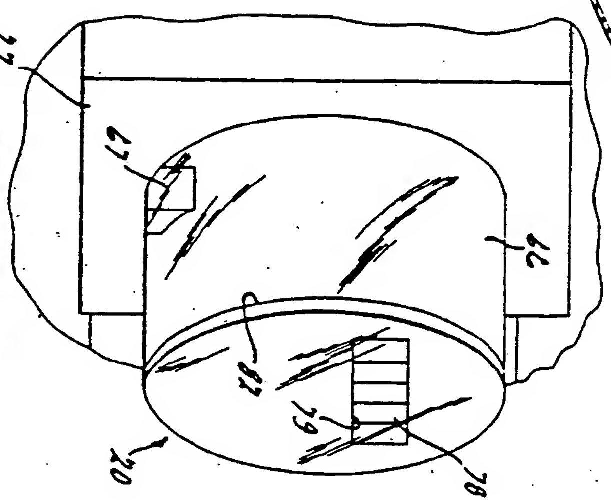

FIG. 6

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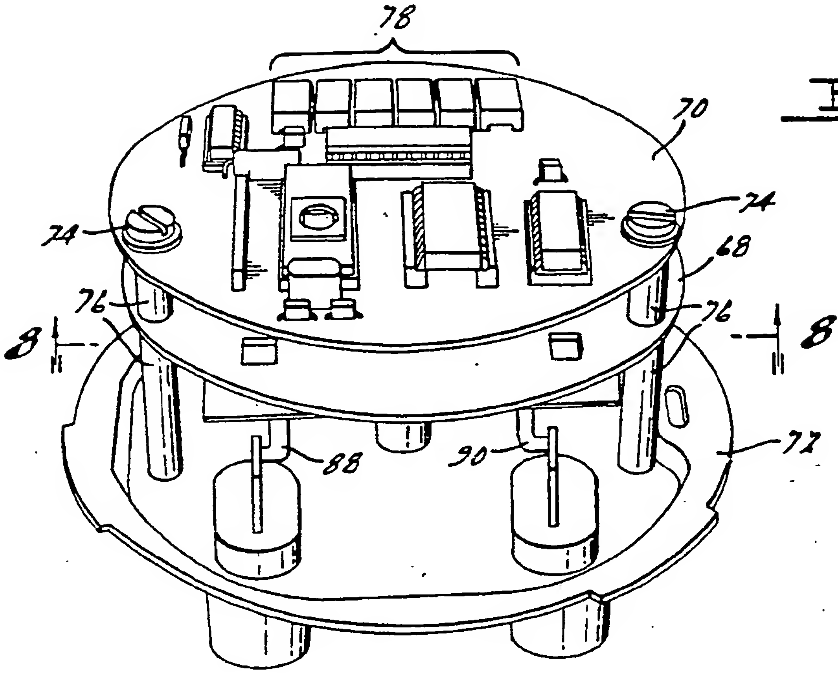


FIG. 3.

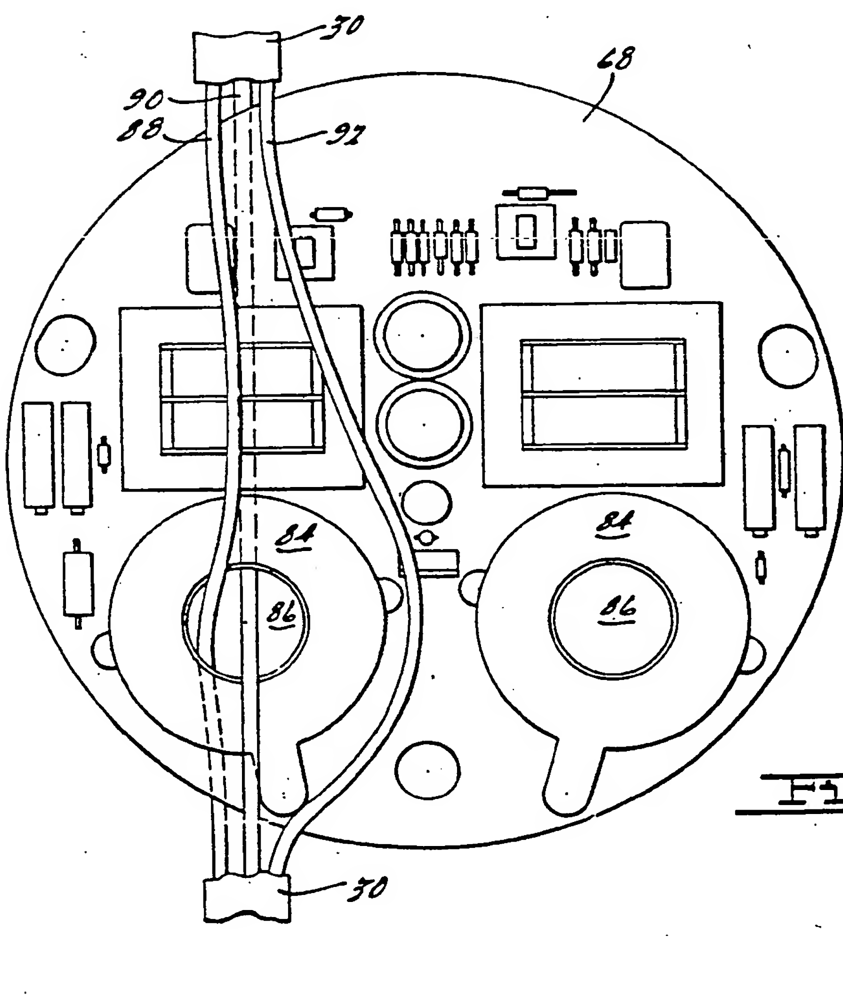


FIG. 8.

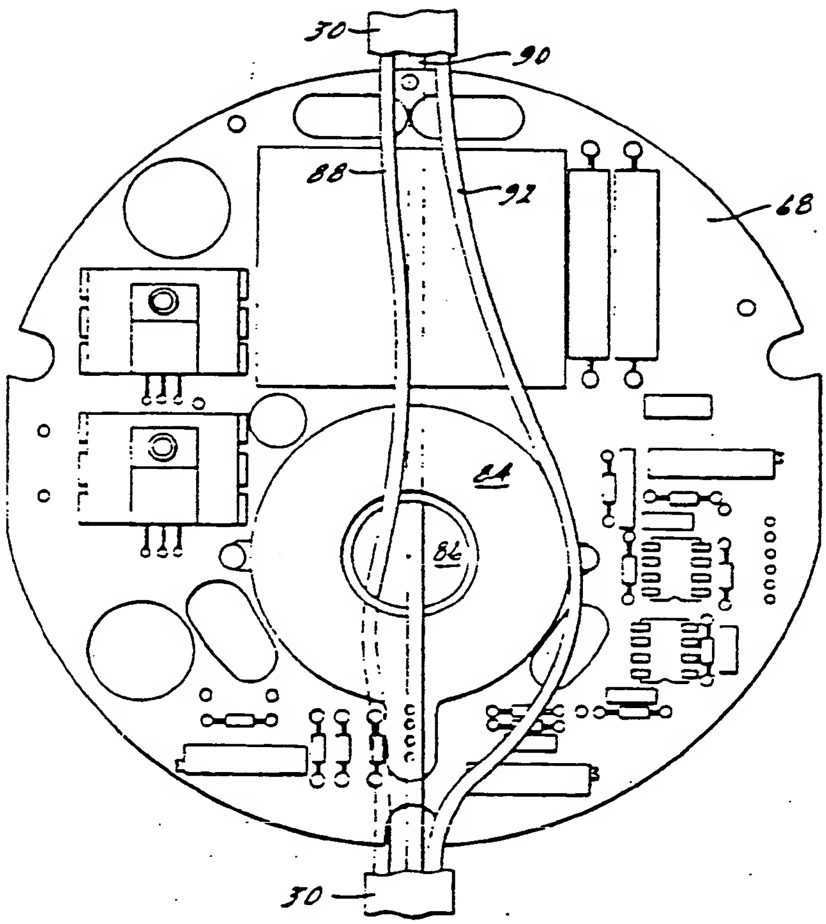
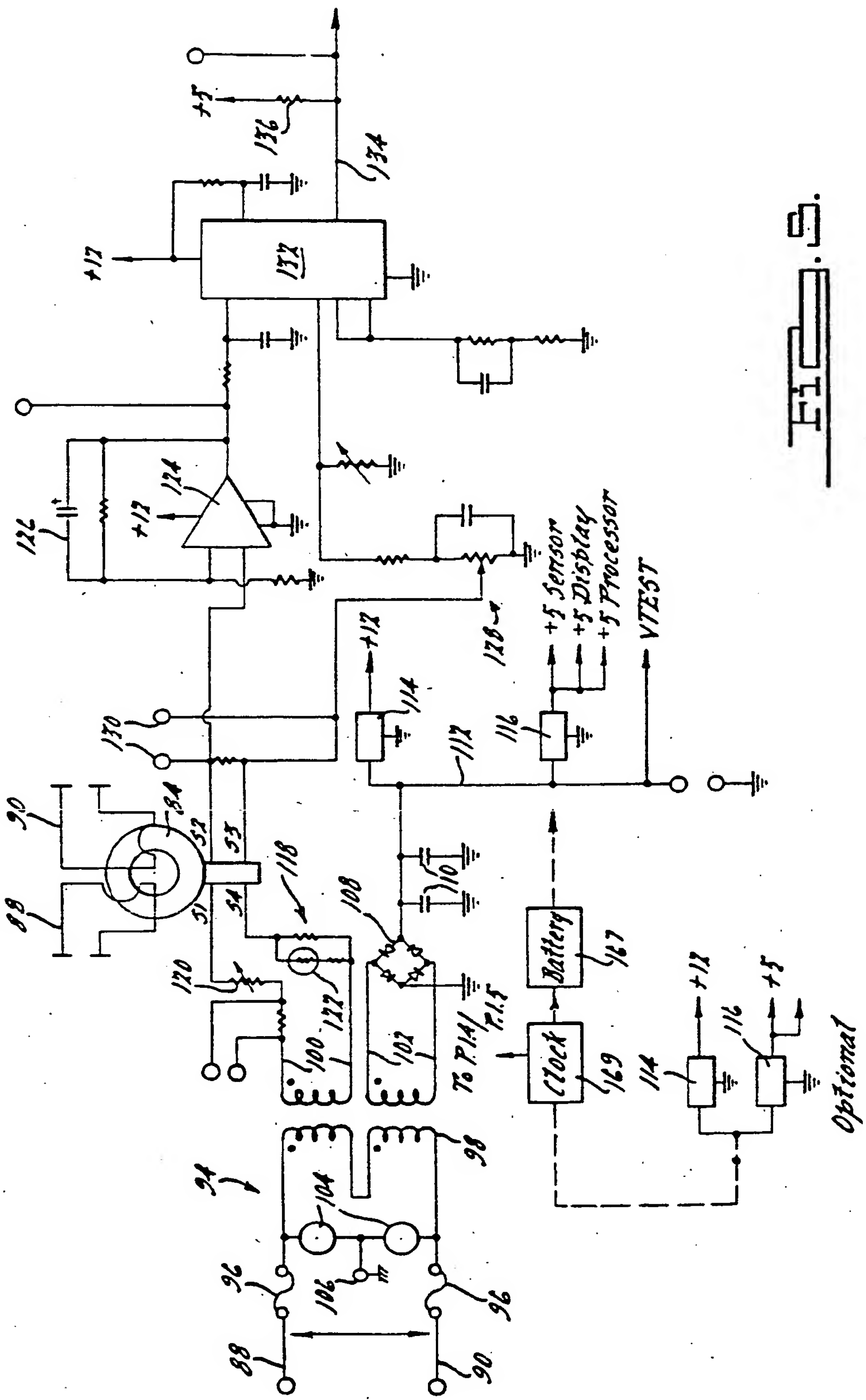


FIG. 4.


+5 Sensor
+5 Display
+5 Processor
VTEST
Battery
Clock
To P.1A/P.1.5
Optional

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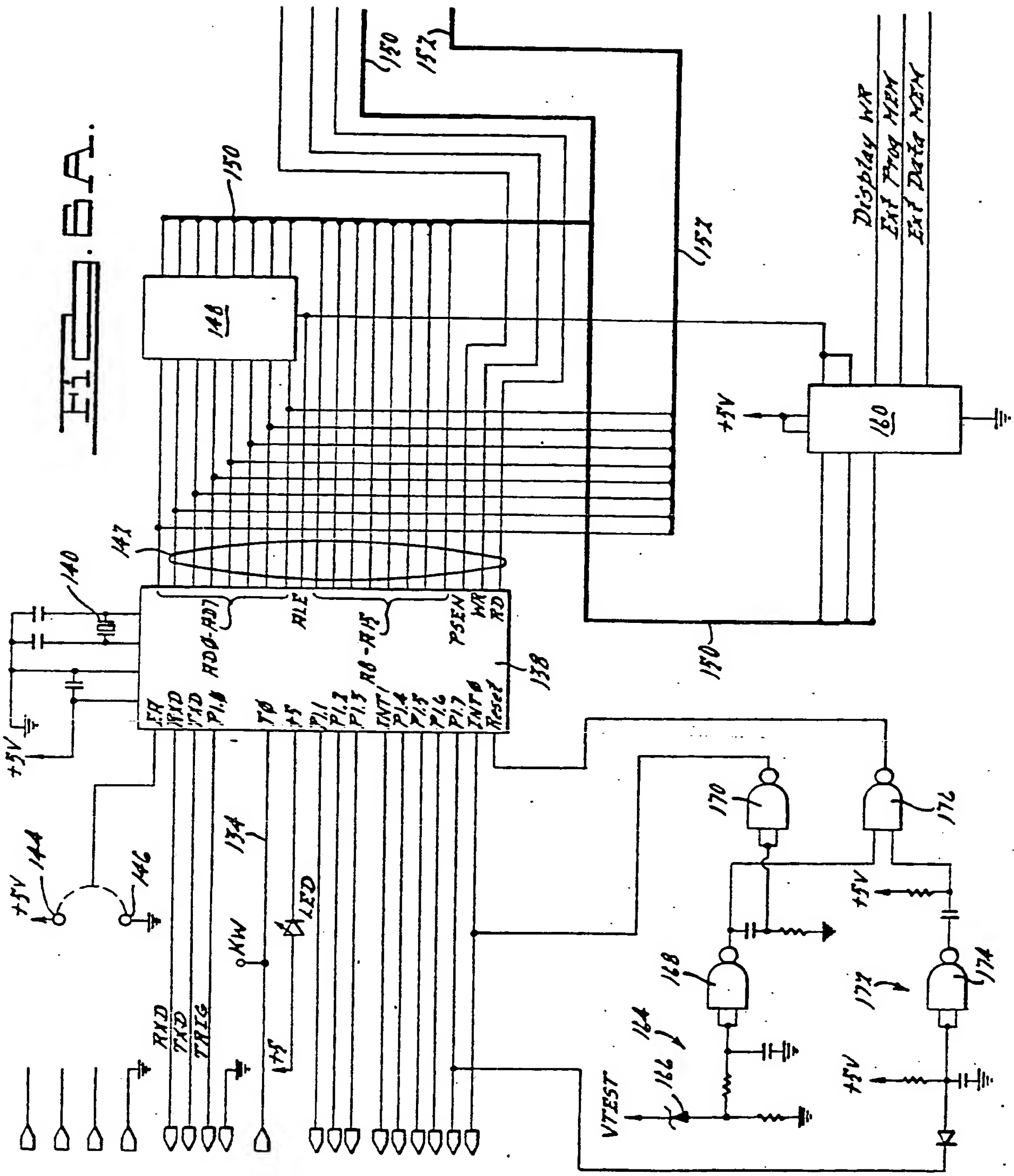

FIG. 6A.

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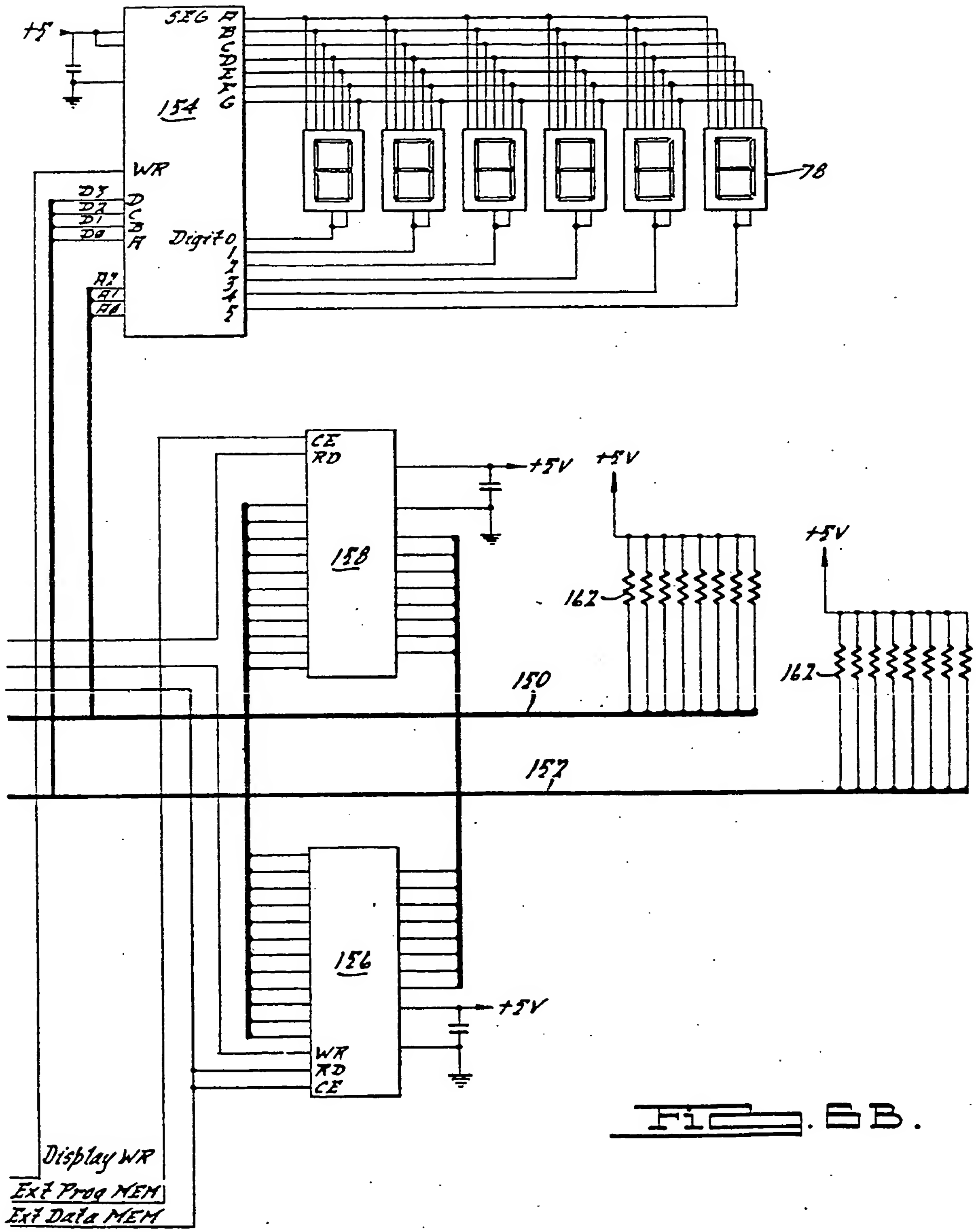

FIG. 6B.

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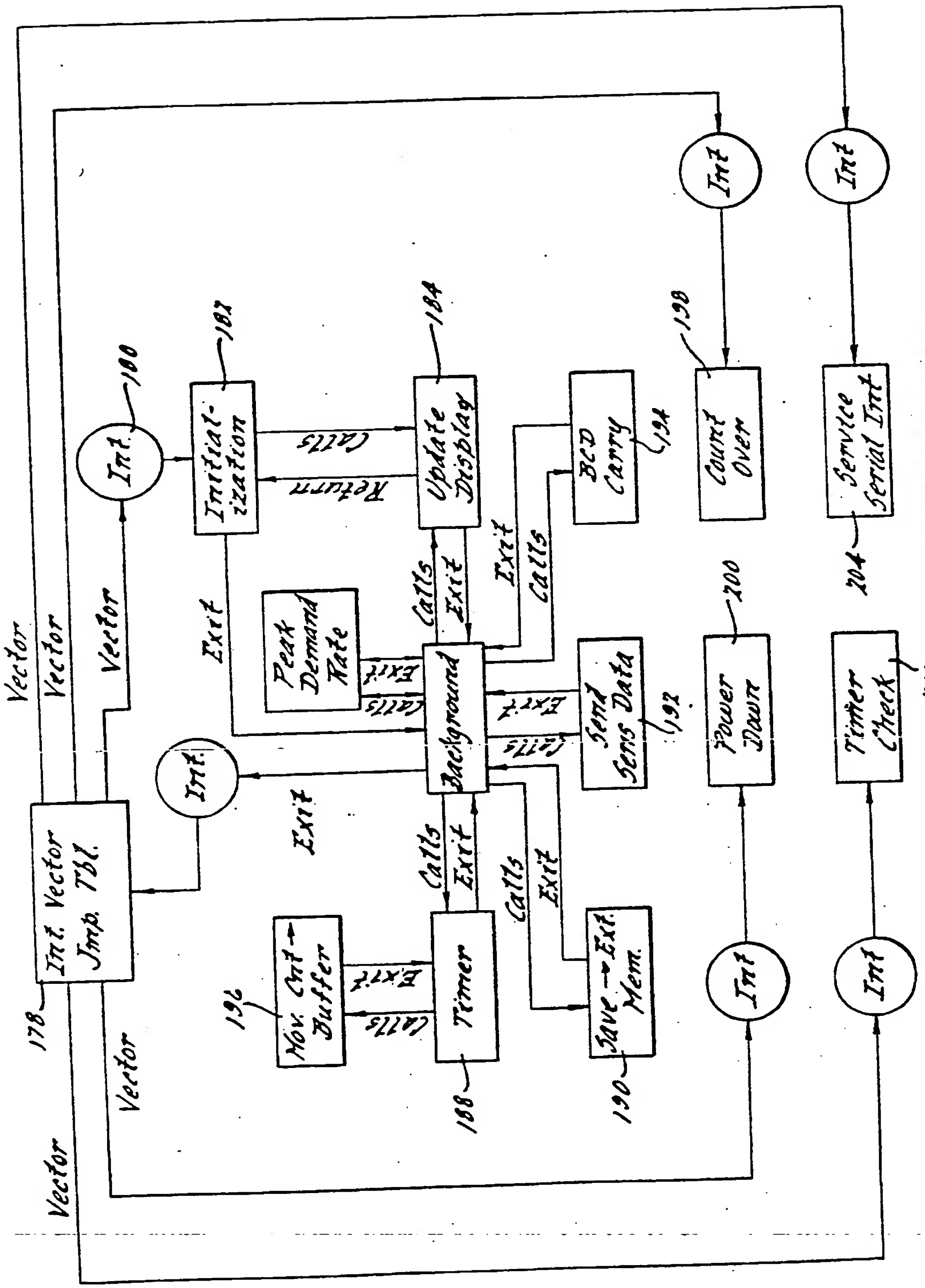

FIG. 7

SPECIFICATION

Utility Meter

BACKGROUND AND SUMMARY OF THE INVENTION

The present invention relates generally to meters for measuring utilities consumed at a residence or business and more particularly to a microprocessor-based automatic remote metering system for measuring the consumption of utilities, such as electric power, water, gas and the like.

Presently utilities, such as electric power, water, gas and the like, are sold to residential and business consumers on a usage metered basis. Generally, separate metering devices are used for each utility, with each meter requiring periodic reading by the consumer or by utility company meter readers. The vast majority of utility meters in used today are either mechanical or electromechanical devices which convert measured utility consumption into some form of rotary movement to advance a rotary dial or cylinder which provides a visual indication of utility consumption. Mechanical or electromechanical meters of this type are inherently inaccurate, particularly at low consumption levels. As an example, a conventional electrical power meter or watt hour meter typically does not respond at energy levels below 32–38 watt seconds. To the electric utility company, the energy consumption below this level represents unbilled energy. The cumulative effect of this lost billing is substantial, when totaled for a year across the entire customer base. In addition, electromechanical meters consume power in making the measurement. The power consumed by a typical watt hour meter costs each consumer an average of about $12.80 a year. Hence, both the utility company and the consumer would benefit from a more accurate and efficient meter.

Aside from inaccuracy and high power consumption, conventional utility meters do not have remote reading capabilities, nor can they be easily retrofitted to include remote reading capabilities. The remote reading capability would eliminate the time and expense of walking door-to-door to read each meter and would, therefore, be a very desirable feature.

Most present day meters are designed to be manually read, say at monthly intervals, and provide a readout of the total cumulative consumption to date. Conventional meters do not provide time of use information, that is, information concerning the instantaneous consumption at a preselected time. In the electric power industry, for example, time of use information can be quite useful and important. Electric consumption is not ordinarily uniform throughout the day. In the summertime, for example, consumption is ordinarily much higher during the hot hours of the day when air conditioning equipment is running. In larger metropolitan areas, particularly those with heavy indurstry, the air conditioner load coincides with the business and industrial load to create a peak energy demand which may be much higher than the average demand throughout the year. To prevent brownouts or blackouts, the electric utility company must have enough ready reserve of generating equipment to supply this peak demand. During off peak hours this reserve is unused. It is naturally expensive to maintain a ready reserve to supply peak demand, particularly since the reserve periodically stands idle. It would, therefore, be desirable to bill electric consumption at a higher rate during peak hours and at a lower rate during off peak hours. In order to apply the correct billing rate, it is necessary to be able to determine not only how much power was used but also when. Time of use metering is, therefore, highly desirable.

In addition to time of use metering for peak/off peak billing purposes, time of use data would also be potentially useful in monitoring the utility needs of the customer base in planning for future expansion, in optimizing the utility network and in trouble shooting power outages and service interruptions. In the electric utility industry, for example, it is helpful to have time of use information when selecting the power rating of distribution transformers, in balancing a three-phase distribution system so that each phase is equally loaded, and in trouble shooting and locating the cause of power surges or dropouts. Present day utility meters are generally deficient in providing this information.

The present invention represents a marked improvement over prior art utility meters. The invention comprises at least one and optionally several means for sensing utility usage. Electric power consumption is measured using a magnetic field responsive device which includes a Hall effect device. The sensor is quite accurate, even at low energy consumption levels, and provides no insertion loss to affect accuracy. In addition to sensing electric power consumption, the invention is also capable of receiving, arbitrating and processing signals from other utility sensors including water flow sensors, gas flow sensors, and other utility metering devices.

The invention further comprises a processor or microprocessor which responds to the utility sensor or sensors and provides digital information indicative of utility usage. A memory, such as a random access memory, is coupled to the processor for storing the digital information. The processor also includes analog to digital interfacing equipment for converting analog signals of the utility sensor into digital signals for manipulation by the microprocessor. A display, such as an LED or liquid crystal 7 segment display, is responsive to

the processor and provides a visual indication of the digital information provided by the processor. In addition, a communication means is coupled to the processor for transmitting the digital information to a location remote from the meter. The communiction means may be adapted to communicate over a telephone system, over a fiber optic communication system or over other communication links, including transmission lines and radio links. When telephone communication is employed, the processor provides an output for serial communication with a modem circuit.

In addition to providing a visual indication of utility usage via the display and a remote indication via the communication means, the invention further comprises a control means for causing the processor to monitor the digital information as it is received or at periodic intervals and to provide an alarm event indication in response to a predetermined fault condition. For example, the processor can be programmed to respond to an interruption in utility service or a degradation in utility service by storing a record of the event and the time at which the event occurred in memory. The memory may be accessed remotely through the communication means to get details of the alarm event even after it has occurred. In the alternative, the processor can automatically provide an alarm event indication to the central office, monitoring substation or other remote location via the communication means. The electronic circuitry of the invention derives its primary operating power from the utility itself and may include a backup power source comprising a storage battery and a low battery detection circuit. Upon primary power failure, the battery backup power source operates the processor and associated circuitry to ensure that no data is lost.

The invention is housed in an enclosure which prevents physical tampering with the electronic circuitry. The entire package, including housing, is capable of being mounted into an existing four-jaw meter socket. The enclosure includes a tamper detection device associated with the housing and coupled to the processor. The tamper detection device transmits a tamper alert signal which the processor can output through the communication means to the home office or monitoring substation. To provide further protection against meter malfunction due to processor lockup, a watchdog circuit is coupled to the processor and provides a reset signal in response to processor inactivity for a predetermined length of time. If the processor becomes inactive or locks up due to tampering or spurious power line signals, the watchdog circuit detects this condition and restarts the processors control routine.

For a more complete understanding of the invention, its objects and advantages, reference may be had to the accompanying drawings and to the following specification.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of the utility meter in an exemplary installation;

Figure 2 is a block diagram illustrating the remote reading meter with a presently preferred telephone telemetry system;

Figure 3 is a frontal perspective view of the meter with protective enclosure removed to reveal the circuit board layout;

Figure 4 is a cross-sectional view taken substantially along the line 4–4 in Fig. 3 and illustrating the underside of the power sensor board;

Figure 5 is a schematic diagram of the power sensor board of the invention;

Figures 6A and 6B comprise a schematic diagram of the processor and display board of the invention;

Figure 7 is a software block diagram of the control means of the invention;

Figure 8 is a cross-sectional view, similar to Fig. 4, illustrating an alternate embodiment of the invention; and

Figure 9 is a frontal perspective view of the meter showing protective enclosure and face plate.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to Fig. 1, the utility meter of the invention is illustrated generally at 20. Meter 20 is installed in conventional four-jaw meter socket 22 which is attached to the lower end of riser conduit 24. Meter socket 22 is secured to the building structure 26, or to a utility pole or other appropriate mounting structure. The electric utility service enters through service drop cable 28, which may include one or more hot conductors and neutral. The electric utility service enters riser conduit 24, passes through socket 22 and enters the building strcuture through entrance cable 30. As will be explained in detail below, meter 20 measures the magnetic field generated by the incoming electric current. Entrance cable 30 enters building structure 26 for attachment to a distribution panel 27 with fuses or circuit breakers in the usual fashion.

One of the advantages of the invention is that it readily provides remote meter reading capabililties through a number of different possible data telemetry systems including telemetry over commercial telephone lines, radio transmissions, fiber optic cables, dedicated transmission lines, AC power lines and the like. Although the invention may be implemented using any telemetry system, commercial telephone lines are quite prevalent and, hence, presently preferred. Accordingly, Fig. 1 illustrates incoming telephone line 32 which enters network interface 34 in the usual fashion. Attached preferably on the customer side or subscriber side of network interface 34 is a

meter interface unit 36 (MIU). Meter interface unit 36 is coupled to meter 20 and provides communication between the meter and the commercial telephone network. Meter interface unit 36 may be housed within the protective enclosure of utility meter 20 if desired.

Another advantage of the invention is its capability of monitoring other utility services besides electric service. In general, the invention is capable of monitoring any metered utility, including gas and water. For purposes of illustrating this aspect of the invention, Fig. 1 depicts water meter 38 and gas meter 40. Meters 38 and 40 are coupled to meter 20 of the invention through connection lines 42. Meters 38 and 40 may be conventional flow measurement meters which include or have been retrofitted with electrical readout capabilities. The electrical readout signals from meters 38 and 40 are delivered to the utility meter 20 of the invention through connection lines 42. Once supplied to meter 20 these readout signals are analyzed, stored and processed for eventual access by the appropriate utility company over telephone line 32. Meter 20 arbitrates which utility signals (electric, gas, water, etc.) are input, stored and analyzed at any given time. The utility signals may be sequentially sampled at a sufficiently rapid rate that sampling error is negligible.

Turning now to Fig. 2, a presently preferred data telemetry system using commercial telephone networks is illustrated. Fig. 2 depicts utility meter 20 with an optional second utility meter (such as water or gas) indicated generally at 44. For purposes of explaining the invention, meter interface unit (MIU) 36 is illustrated as external to meter 20. Of course, as stated above, meter interface unit 36 may be incorporated within the utility meter package itself. Meter interface unit 36 is coupled to meter 20 through input leads 46 which have also been given the individual designations RXD, TXD and TRIG used in Fig. 6A and discussed below. The output of meter interface unit 36 couples to tip wire 48 and ring wire 50 of the test trunk line of a commerical telephone network. The tip and ring wires are in turn connected through network interface 34 to the telephone company network or loop 52 which routes calls to the utility customer by means of switching circuits within telephone company central office 54. The test trunk line may be accessed by the switching circuits in the conventional fashion to access a customer's phone circuit without activating the ringer.

In order to communicate with the meter interface unit the utility company, e.g. the electric utility company, has a data communication terminal 56 which includes a computerized processor subsystem 58 and data communication interface unit 60 which is coupled through the telephone network or through a dedicated phone line 62 to the MRAC unit 64 within the telephone company central office.

When a particular customer's meter is to be read, the computerized processor subsystem 58 dials or accesses the MRAC unit 64 in central office 54, thereby sending a request for a certain customer's meter to be read. The MRAC unit 64 accesses the customer's phone line through the test trunk line. The MRAC unit opens the line to the customer's phone but does not assert a ring signal (so the residential phone does not ring). Instead, the MRAC unit asserts a special tone that triggers the meter interface unit 36. Upon being triggered, meter interface unit 36 reads the data corresponding to utility usage which is supplied to it by the circuitry of meter 20 discussed below. The meter interface unit then assembles or packages the data in a predefined format or protocol and transmits that data back to the MRAC 64. The MRAC in turn interprets or unpackages the MIU data and reports it back to the computerized processor subsystem 58 where the customer's utility consumption and time of use data is analyzed.

While other communication circuits are also possible, the presently preferred meter interface unit includes at least one universal asynchronous receiver transmitter (UART), a Bell 103 standard modem circuit (300 baud) and an active bandpass filter. Preferably the meter interface unit is implemented using CMOS integrated circuitry so that the entire unit runs on power supplied by the telephone line. A suitable meter interface unit is available from Base 10 Systems, Trenton, New Jersey. Other meter interface units are also useable, however.

Figs. 3, 4 and 9 illustrate the presently preferred physical layout of the invention. The invention is adapted to plug directly into existing four-jaw meter sockets, such as socket 22 (Fig. 9). The circuitry is housed within a protective glass or plastic enclosure 66 which has an overall size and shape comparable to the glass enclosures found on conventional electromechanical watt hour meters. If desired, a microswitch 67 or other sensor can be positioned to contact the enclosure 66 so that removal of the enclosure will be detected. Figs. 3 and 4 illustrate the meter with enclosure removed. The electronic circuit which comprises meter 20 is preferably assembled on two spaced aprt and parallel circuit boards 68 and 70. Both boards are circular to conform to the interior shape of protective enclosure 66. Circuit board 68 is the current sensor board and circuit board 70 is the processor/display board.

Preferably circuit boards 68 and 70 are assembled on base plate 72 by means of bolts 74 and spacers or standoffs 76. The boards may be assembled with their respective foil sides facing one another. Secured to the component side of processor display board 70 are a series of seven-segment LED or liquid crystal alphanumberic display devices 78. Display

devices 78 are positioned behind a rectangular opening 79 in the face plate cover 82 (Fig. 9) and are, therefore, visible through the protective enclosure 66.

Current sensor board 68 carries at least one toroidal Hall effect sensor 84 (two are shown in Fig. 8). Hall effect sensors 84 have a circular opening 86 aligned with a similar opening through board 68 through which the current delivering conductors are fed. Fig. 4 illustrates entrance cable 30 as comprising three individual conductors 88, 90 and 92. Conductor 92 is the neutral conductor and conductors 88 and 90 are the current delivering conductors coupled to the secondary windings of a pole mounted or pad mounted stepdown transformer. According to customary practice, conductors 88 and 90 are both ultimately wired to the distribution panel along with the neutral conductor 92. Standard 110 volt outlets are then connected between the neutral conductor 92 and either one or the other of conductors 88 and 90. If required, 220 volt outlets are wired across conductors 88 and 90. Conductors 88 and 90 are both hot conductors carying currents which are 180 degrees out of phase. To ensure that all power delivered to the building is metered and billed, conductors 88 and 90 are both fed through circular opening 86 in one of the toroidal Hall effect sensors 84. Since the currents on these two conductors are out of phase with one another, one conductor is fed upwardly through opening 86 and the other conductor is fed downwardly through opening 86, so that the magnetic fields surrounding the two conductors add to one another. This is shown in Fig. 4 and also in Fig. 8.

In the alternate embodiment illustrated in Fig. 8, two toroidal Hall effect snesors 84 are illustrated although only one is being used; the other remains unused. A second and even a third Hall efect sensor may be included for use in muliphase applications. In the atlernative, additional Hall effect sensors may be used to meter the power consumption of a different customer at the same address. In duplex apartments, one meter could, therefore, be used to service both tenants. In single customer applications and single phase applications, the additional Hall effect sensors may be eliminated if desired.

Referring to Fig. 5, the power sensor circuitry associated with circuit board 68 is illustrated. The current sensor circuit comprises a power supply circuit indicated generally at 94. Power supply circuit 94 is receptive of electrical energy by coupling to conductors 88 and 90 through fuses 96. Fuses 96 are in turn connected to the primary leads of stepdown transformer 98, which provides two pairs of secondary winding outputs 100 and 102. Metal oxide varistors (MOV) 104 are coupled between each of the fuses and the external ground 106 to provide surge protection. Secondary leads 102 supply stepped down alternating current to full wave bridge rectifier 108 to which filter capacitors 110 are coupled. The negative side of rectifier 108 is grounded and the positive side is connected to a voltage supply bus 112 to which voltage regulators 114 and 116 are connected. Preferably voltage regulator 114 supplies 12 volts DC while voltage regulator 116 supplies 5 volts DC.

Secondary leads 100 are coupled through a resistor network 118 to the toroidal Hall effect sensor 84. Resistor network 118 includes an adjustable rheostat 120 and a temperature compensating thermistor 122. Hall effect sensor 86 may be implemented using a PI Series current/watt sensor manufactured by F. W. Bell, Orlando, Florida. Sensor 86 provides two bias leads S1 and S4 and two output leads S2 and S3. Sensor 86 operates on the principle of Ampere's law which states that the current in a conductor produces a proportional magnetic field surrounding the conductor. The sensor includes a gapped toroidal core with a Hall generator mounted in the gap. The core concentrates the magnetic field produced by the current in the conductor which passes therethrough and passes that magnetic field through the Hall generator. The Hall generator is a magneto-sensitive semiconductor which provides an output voltage proportional to the product of the magnetic field normal to its surface and the control current flowing through it at the bias voltage. The control current is supplied through bias terminals S1 and S4. The Hall effect sensor (being responsive to both the current flow and the bias voltage) is proportional to the power consumed. The output voltage of sensor 86 is delivered to operational amplifier 124 which is configured with feedback capacitor 126 to act as an integrator. The output of operational amp 124 is an analog DC level proportional to the time integral of the power sensed by sensor 84.

In addition to adjustment rheostat 120, the circuit also includes a bias potentiometer 128 for adjusting the level of signals input to operational amp 124. A pair of test terminals 130 are provided at both sensor output terminals S2 and S3. By shorting out test terminals 130 during calibration, sensor 84 is effectively removed from the circuit and no input signal is fed to operational amplifier 124. In this state, potentiometer 128 may be adjusted to produce a zero volt DC level at the output of amplifier 124. With the short removed from terminals 130 and with either a known test current or not test current flowing through the opening 86 of sensor 84, adjustment rheostat 120 can be tuned to produce the correct output at operational amplifier 124.

The output from operational amplifier 124 is delivered to a voltage to frequency converter 132, which may be implemented using a LM 131 integrated circuit. The voltage to fre-

quency converter effects a form of analog to digital conversion. The conversion is made by sampling the converters output on lead 134 for a fixed-time interval and counting the number of pulses or oscillations produced. The number of pulses or oscillations produced is proportional to the DC level supplied by amplifier 124. Knowing the sampling time interval, the number of counted pulses is proportional to the DC level and, hence, is indicative of the energy flowing through the circular opening 86 of sensor 84. Coupled to output lead 134 is a pullup resistor 136 which is coupled to the five volt supply makes the output of converter 132 compatible with digital logic levels.

Turning now to Figs. 6A and 6B, the processor/display circuit comprises microprocessor 138, such as an Intel 8751 microprocessor. In Fig. 6A the input and output leads of microprocessor 138 have been labeled with their customary designations. External crystal 140 provides a 4 MHz. time base. Microprocessor 138 communicates with the address/data bus 142, which provides 8 parallel data bits and 16 parallel address bits. Microprocessor 138 also includes 8 serial input/output ports P1.0–P1.7. Microprocessor 138 includes internal random access memory (RAM) and is also capable of addressing external memory through the address/data bus 142. When internal memory is being used, the EA terminal of microprocessor 138 is jumpered to the five volt supply as with jumper connection 144. When external memory is being used in place of the internal memory, the EA terminal is jumpered to ground as with jumper 146. Microprocessor 138 includes an external timer input (TO) to which the voltage to frequency converter output lead 134 is connected. The receive and transmit serial data terminals (RXD and TXD), together with input/output port P1.0 (used for trigger signals) communicate with a meter interface unit, such as unit 36 (Fig. 2). Microprocessor 138 also includes interrupt terminals INT1 and INTO and a reset terminal RESET. To provide a proper interface between microprocessor 138 and external memory, latch circuit 148 is provided. Latch 148 may be implemented using a 74LS373 integrated circuit and is coupled to the shared address/data lines of address/data bus 142. The output of latch 148 comprises the least significant bits (LSB) of the 16 bit address word. Together with the remaining address lines of bus 142, the output of latch 148 provides the address bus 150. The data bus 152 is derived from the input leads to latch 148. The address latch enable or ALE terminal of microprocessor 138 provides the logic signal to indicate whether the information input to latch 148 is address information or data information.

In the presently preferred embodiment the local display of kilowatt hours consumed is provided by 7 segment display devices 78. Display devices 78 are driven by display driver circuit 154, which may be a ICM7218D integrated circuit. The display driver is addressed by the A0, A1 and A2 address lines. Data is provided on the D0–D3 data lines.

In addition to the internal random access memory within microprocessor 138, the invention also includes nonvolitile data storage memory 156 and optional program storage memory 158. Memory 156 may be implemented using EEPROM devices such as a 2816 integrated circuit. Program memory 58, if used, may be a 2716 integrated circuit EPROM, or the like. In order to permit microprocessor 138 to selectively address the data storage memory 156, the program memory 158 or the display driver 154, a device select circuit 160 is provided. Circuit 160, which may be a 74LS138 integrated circuit, is coupled to the most significant address lines A13–A15 and provides device select output signals to the write terminal WR of display driver 154 and to the chip enable terminals CE of memory circuits 156 and 158. Microprocessor 138 can select which of these devices it needs to address by placing the appropriate address signals on address lines A13–A15. Memory circuits 156 and 158 are also coupled to the Read RD and write WR terminals of microprocessor 138 in the usual fashion. As illustrated, data bus 152 and most significant bits A8–A15 of address bus 150 are connected through pullup resistor banks 162 to the five volt supply.

As discussed above, the electronic circuit of the invention is primarily powered by connection to the incoming AC line. The circuit is also capable of being powered from an auxiliary battery supply power source 167 as discussed above to operate a real time clock 169, which communicates with ports P1.4 and P1.5 and is used in time of use measurements. To protect against faulty readings during brownouts, a voltage monitoring circuit 164 is provided. Circuit 164 includes a Zener diode 166 which is coupled to the VTEST test point on voltage supply bus 112 (Fig. 5). When the voltage on supply bus 112 drops below the Zener threshold, logic gate 168 initiates a signal which in turn causes logic gate 170 to generate an interrupt signal on the INTO line of microprocessor 138. The zero interrupt is a high priority interrupt which causes microprocessor 138 to effect a power shutdown routine whereby all data currently being processed is stored in nonvolatile data storage memory 156 along with the microprocessor machine state. The routine thus preserves valid data and causes potentially invalid subsequent data to be ignored. Once proper voltage levels have been restored, microprocessor 138 recovers its former machine state and continues processing data in the usual fashion.

For protection against program lockup,

watchdog circuit 172 is provided. During normal operation, microprocessor 138 executes a programmed set of instructions (contained within internal memory or optionally within program memory 158). Should a power surge or momentary power dropout occur, or should someone attempt to tamper with the programmed instructions, it is possible for a program lockup to occur. Lockup occurs when the program counter within micrporocessor 138 loses its place in the program and the microprocessor attempts to execute an unintended instruction, often with unpredictable results. To protect against such lockup, microprocessor 138 is programmed to periodically send a watchdog signal via port P1.7. Logic gates 174 and 176 monitor the watchdog signal and respond when the watchdog signal is absent by resetting microprocessor 138 via the RESET terminal. Thus, if microprocessor 138 locks up and ceases to send watchdog signals, the processor is reset to a predetermined starting point within the control program.

With the foregoing hardware description of the invention in mind, the control program will now be described. Referring to Fig. 7, the control program executed by microprocessor 138 is illustrated in terms of its functional subroutines or modules. In Fig. 7 the modules are represented by blocks, interconnected to ilustrate program control flow. Interrupt events are depicted by circles. Preferably the control program is written in assembly language or machine language and stored within some form of nonvolatile memory, either in the microprocessor's internal memory or within optional program memory 158. The control program may be coded directly as assembly language instructions or it may be compiled or interpreted using higher level computer languages to implement the algorithm of Fig. 7.

Preferably the control program implements both hardware and software interrupts; and, accordingly, the control prgram includes an interrupt vector jump table 178. When a hardware or software interrupt occurs, the control program consults the interrupt vector jump table to determine where program control should resume, based on the interrupt number or its identity. For example, a reset signal on the RESET terminal is treated as a hardware reset interrupt. Similarly, interrupts received on INT0 and INT1 lines are also hardware interrupts. The number zero interrupt (INT0) is used to initiate the power down mode, while the number one interrupt (INT1) is used for transmitting data. Other interrupts, including software interrupts, may also be included in the jump table. The other interrupts will be discussed in connection with the portions of the program which generate those interrupts.

Upon power up or upon a hardward reset, denoted at 180, program control enters the initialization routine 182. The initialization routine initializes the microprocessor's serial port to the communication baud rate (e.g. 300 baud). The microprocessor's internal timer 1 is used to generate the serial port baud rate. The serial port is configured for one start bit, one stop bit and eight data bits. At this time, the interrupt for the serial port is enabled and the number one interrupt (INT1) is also enabled. The initialization routine then reads data storage memory 156 to obtain the last stored data, indicative of energy usage to date. The last stored data is then written to display devices 78 by calling the update display routine 184 decribed further below. Upon completing the initialization process, initialization routine 182 exits to background routine 186.

Background routine 186 is the normal operating routine from which the other routines are called. It coorindates the other routines, calling them when necessary. Program control does not normally exit from background routine 186, unless caused to do so by a hardware interrupt. As illustrated in Fig. 7, background routine 186 can call a number of different routines, including timer routine 188, save to external memory routine 190, send sensor data routine 192, binary coded decimal carry routine 194 and update display routine 184. When one of these routines is called by background routine 186, control branches to that routine and then returns to the background routine when finished.

Many of the routines are called by background routine 186 at periodic time intervals. Timer routine 188 and time check routine 202 are responsible for providing timing information to the background routine. The timer check routine 202 is responsive to the timer 1 interrupt produced internally by the microprocessor. Timer check routine 202 measures various time intervals by incrementing software counters and provides an indication of the measured time intervals by setting software flags. One such flag is a 10 millisecond flag which background routine 186 uses to call timer routine 188. Another flag is the calibration flag which is set and reset every 100 milliseconds and causes microprocessor ports P1.4 and P1.5 to alternately toggle between set and reset states. During meter calibration, ports P1.4 and P1.5 are monitored to determine whether critical timing functions are within specifications.

Timer routine 188 works in conjunction with timer check routine 202 to keep track of the times at which the other routines are called from background. Timer routine 188 is called from background every 10 milliseconds as determined by the 10 millisecond flag controlled by timer check routine 202. Timer routine 188 controls software counters which measure time intervals of 20 milliseconds, 100 milliseconds and 1 second. Software flags are set and reset to convey this timing information to background routine 186. The 20 millisecond

timer is used to regulate the speed at which data is written to data storage memory 156 following a write instruction from the microprocessor. The 100 millisecond timer is used to control the rate at which data is transmitted through the communication port in response to a trigger signal on port P1.0. The 1 second timer is used to prevent creep. Creep is a phenomenon caused by noise in the analog circuitry whereby the value indicative of energy usage slowly creeps up or increases when no energy is being consumed. This creep is corrected for by discarding energy consumption data which is below the noise threshold level. Once each second the data is tested for creep, and if above the noise threshold, the present reading data is placed in a temporary storage buffer by calling the move count to buffer routine 196. Routine 196 stores the present reading where it may be accessed by other routines, such as the save to external memory routine 190.

The save to external memory routine 190 is called by background routine 186 every 20 milliseconds (as determined by timer routine 188). Routine 190 moves the data from the temporary buffer to the data storage memory 156. Preferably this data is stored in a binary coded decimal or ASCII format. Routine 190, by virtue of the 20 millisecond delay, allows the data captured in the temporary buffer to be written to the comparatively slower nonvolitile memory device of data storage memory 156 without delaying the other routines.

The send sensor data routine 192 transmits data through the serial communication port. If a trigger signal is received from meter interface unit 36, then following a 100 millisecond delay, the present meter reading is sent at 300 baud through the serial port with even parity. A header comprising an ASCII asterisk character followed two additional ASCII characters receives the present meter reading value. If stored as binary coded decimal digits, the meter reading value is converted to ASCII prior to being transmitted. The service serial interrupt 204 works in conjunction with the send sensor data routine 192. The serivce serial interrupt 204 responds to an interrupt generated when the meter interface unit wishes to communicate with the microprocessor. Routine 206 determines whether the communication request is to receive or transmit data. If a request to transmit is sent, routine 206 sets a flag which enables the send sensor data routine 192.

The update display routine 184 causes the data indicative of watt hours consumed to be displayed on display devices 78. Routine 184 does this by enabling display driver 154 using device select circuit 160. Driver 154 is then addressesd and data is output to the display devices in binary coded decimal format. In order to implement a binary coded decimal format, binary coded decimal carry routine 194 is called to check and determine whether the most significant digit is over 10, in which case a carry to the next decimal place occurs.

In addition to the routines called from the background routine, the program also includes other interrupt driven routines. Power down routine 200 is responsive to the number zero interrupt (INT0) which is activated by voltage monitoring circuit 164. As explained above, circuit 164 generates the number zero interrupt when the AC line voltage drops below a safe level. The power down routine 200 freezes the internal clock, causing all functions to stop. The present meter reading is retained in memory 156 and a hardware reset is initiated so that the power is restored and the control resumes at routine 182.

The routine for interpretting the power usage data on line 134 is the count over routine 198. The count over routine is an interrupt driven routine responsive to the internal counter zero overflow interrupt. At the beginning of every 10 millisecond interval, the background routine sets an internal zero counter to count a predetermined number of base counts which represent the quiescent meter state. At the beginning of every 10 millisecond interval, the zero counter is set to count the number of base counts. After the base counts have been counted, the number of pulses on line 134 needed to make one watt is determined. A flag is set when one watt is reached. This flag is checked in background, whereupon the watt is added to the binary coded digits already in the memory. For every watt hour counted, a flag is set to update the display.

While the invention has been described in its presently preferred embodiment, it will be understood that the invention is capable of certain modification and change without departing from the spirit of the invention as set forth in the following claims.

CLAIMS

1. A utility meter comprising:

a means for sensing utility usage;

processor means responsive to said sensing means for providing digital information indicative of utility usage;

memory means coupled to said processor means for storing said digital information;

display means responsive to said processor means for providing a visual indication of said digital information; and

communication means coupled to said processor means for transmitting said digital information to a location remote from said meter.

2. The utility meter of Claim 1 wherein said processor means includes auiliary input means for determining a second utility usage.

3. The utility meter of Claim 1 further comprising an enclosure for housing at least said processor and said memory, and comprising tamper detection means associated with said

housing and coupled to said processor means for transmitting a tamper alert signal in response to tampering with said enclosure.

4. The utility meter of Claim 1 wherein said communication means includes a modem circuit means for communicating over a telephone system.

5. The utility meter of Claim 1 wherein said communication means is a serial communication means.

6. The utility meter of Claim 1 wherein said communication means is an asynchronous communication means.

7. The utility meter of Claim 1 wherein said communication means is an optical signal communication means.

8. The utility meter of Claim 1 wherein said communication means includes means for generating optical signals and means for coupling said optical signals to a fiber optic cable.

9. The utility meter of Claim 1 wherein said sensing means includes a Hall effect sensor.

10. The utility meter of Claim 1 wherein said sensing means includes a magnetic field responsive means.

11. The utility meter of Claim 1 wherein said sensing means comprises a toroidal magnetic field responsive means and Hall effect means coupled to said toroidal means.

12. The utility meter of Claim 1 further comprising control means for causing said processor means to monitor said digital information and to provide an alarm event indication in response to a predetermined fault condition.

13. The utility meter of Claim 12 wherein said predetermined fault condition is an interruption in utility service.

14. The utility meter of Claim 12 wherein said predetermined fault condition is a degradation in utility service.

15. The utility meter of Claim 12 further comprising clock means coupled to said processor means for determining the time of said fault condition.

16. The utility meter of Claim 1 further comprising auxiliary power means for providing operating power to said processor.

17. The utility meter of Claim 1 wherein said processor means includes means for disabling said display means at preselected times.

18. The utility meter of Claim 1 further comprising watchdog circuit means coupled to said processor means for providing a reset signal to said processor in response to processor inactivity for a predetermined interval.

19. The utility meter of Claim 1 further comprising battery backup power source and low battery detection means.

20. A utility meter comprising:

at least one sensor for providing a first signal indicative of utility usage;

convertor means coupled to said sensor for providing a digital signal indicative of said first signal;

processor means receptive of said digital signal and having timing means for determining time intervals;

memory means coupled to said processor means;

control means for causing said processor means to store digital values indicative of said digital signal in said memory means at predetermined time intervals.

21. The utility meter of Claim 20 wherein said sensor includes a Hall effect sensor.

22. The utility meter of Claim 20 further comprising interrogation means for causing said processor means to recover said digital values and to transfer said recovered digital values to a location remote from said meter.

23. A utility meter constructed and arranged to operate substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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